

Multi-Neutron detection in R^3B at FAIR with alternative detector model

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For the determination of excitation energies in nuclear reactions a high neutron energy resolution and a reliable detection are very important. In the future R^3B experiments at FAIR, this will be performed by the New Large Area Neutron Detector (NeuLAND), which is based on a fully-active scintillator concept. NeuLAND consists of 3000 scintillator modules to achieve precise time and position measurements required for the momentum determination via time of flight. Neutrons, emitted from the target, scatter in the scintillator material which leads to the production of charged particles, which deposit energy in a detector module. A dedicated reconstruction algorithm has to find the first interaction of an incident neutron by analysing an event pattern, which will provide necessary measurements for the calculation of the neutron energy [1]. A series of test experiments have been performed at GSI SIS18 with the NeuLAND prototype and the results were compared with the calculations using the R^3B Root framework. An agreement of multiplicity, single paddle energy deposit and total energy deposit distributions has been achieved after introducing a shorter integration time of ≈ 20 ns and extending the simulation with an effect of photomultiplier saturation and presence of QDC thresholds. Such an alternative algorithm had to be applied on simulations of the full NeuLAND detector with respect to multi-neutron reconstruction performance. This report shows comparison of described model versus results published in NeuLAND TDR [2].

Simulations

The simulations have been realised using the R^3B Root framework. Secondary particles, created via neutron interaction with the scintillator material, may travel through several modules, thus creating various signals. On its way to the photomultiplier the signal amplitude is reduced because of light attenuation and the finite lifetime of excited states. Those two parameters are given by material constants. The energy loss values from different charged particles are integrated within time window of ± 20 ns around the first signal, which is significantly lower than was used for the results in [2]. This integration time has to be reconsidered in order to match the read-out set-up of NeuLAND electronics, and can not be used in future simulations as a free parameter. In the next step of the reconstruction, saturation of a photomultiplier is taken into account. The saturation has the form $E' = E \cdot (1 + k \cdot E)^{-1}$ leading to an decreasing output with higher energies. In the final step the energy gets additionally smeared with a Gaussian with 4 % resolution. Due to the modular setup of NeuLAND and the time difference between the two signals in one mod-

ule, the position of a crossing particle can be determined in both directions. Signals close in space and time are then combined in so-called clusters. Subsequently an algorithm tries to identify secondary hits. Afterwards the number of neutrons is determined from a combined condition on the number of clusters and the total deposited energy in NeuLAND.

Result

Table 1 shows the comparison of results with introduced limited integration time and PMT saturation versus the results from NeuLAND TDR for events with 3 and 4 incident neutrons. There is no significant change in the detection efficiency, but an increase of 3n to 4n misidentification due to declined energy resolution.

		3N	4N
3N	old	55	32
	new	60	34
4N	old	10	57
	new	18	59

Table 1: Comparison of detection efficiency and misidentification of events with 3 and 4 incident neutrons, obtained with the alternative model, versus benchmark results from [2]. The input is ^{132}Sn beam with an energy of 600 AMeV, a relative fragment energy of 500 keV and a distance of 15 m to the target. The columns represent the generated events and the rows the corresponding detected ones.

The decrease of the identification efficiency for one and two-neutron events, as the result of declined total energy resolution, was observed and has to be investigated in details. The work is ongoing in the direction of finding alternative parameters in the model, besides integration time, adjusting which might allow to have an agreement with the prototype experimental data and better full NeuLAND performance in simulation. In addition, the resolution of relative energy reconstruction of one neutron from a reaction with a beam energy of 600 AMeV, a relative energy of 100 keV was studied at a distance of 35 m between NeuLAND and the target. The resulting value is 13 keV, which fulfils the design goal for NeuLAND [2].

References

- [1] D. Kresan *et. al*, GSI Scientific Report **2011**, p. 175
- [2] R^3B Collaboration, Technical Design Report of NeuLAND **2011**